SHORT TERM SCIENTIFIC MISSION (STSM)
SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA15127- Resilient Communication Services Protecting End-user Applications from Disaster-based Failures (RECODIS WG3: Technology-related disasters)
STSM title: Resilience modelling approach for integrated ICT and power systems
STSM start and end date: 22/04/2019 to 29/04/2019
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PURPOSE OF THE STSM:

Future smart grid systems are likely to be heavily information and communication technology(ICT)-reliant to cover real-time processes, market operation, demand response schemes and so on. However, failures in one subsystem may impact another subsystem through cascading failures and lead to large scale blackouts. One such set of failures are technology based failures. Forexample, failures in ICT system may propagate to power systems through their interdependencies and lead to technological based disasters such as large scale blackouts. To assess the impact of technology based failures, models that encompass ICT and power systems are required.
We assume high reliance of power grid on ICT systems making power grids vulnerable to ICT related failures. The purpose of the STSM was to:

1) Analyze characteristics of scenarios that include power and ICT systems suitable for modelling purposes.
2) Understand modelling techniques and their suitability to ICT-reliant power grid use cases.
3) Discuss metrics of interest that could be used to measure resilience of system of interest.
4) First approach to model the system of interest.

The STSM fits in the scope of WG3: Technology-related disasters.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

This STSM was implemented at Norwegain University of Science and Technology(NTNU), Trondheim, Norway and was hosted by Prof. Bjarne Helvik.

The issue of ICT resilience has been extensively studied in literature in recent years and is now being considered in context of power grids. Future power grid scenarios include high ICT penetration that allow near complete grid automation. The work carried out in this STSM was related to the modelling of future ICT reliant-power grids for resilience assessment.

The first task carried out in the STSM was to analyze current state of the art and characteristics of ICT-reliant power grids. A number of scenarios were considered including overloading,

underloading, day ahead scheduling that could lead to various different outcomes such as cascading line failures, blackouts, instabilities in failure situations etc and must be handled adequately to avoid failure propagation with disastrous outages as a consequence and simultaneously maintain an acceptable level of power supply. The focus was on failures originating from ICT and propagating into power systems.

Stochastic activity nets(SAN) was introduced as a modelling technique including the Moebius tool and related literature. A gentle introduction into SANs was given. SANs could be used as a modelling technique in the future.
Concerning quantification of resilience, a metric needed to be selected by which system state could be defined. The system state would be impacted by an event which ultimately results in a change in system state. It was assumed that the power grid is heavily ICT reliant and the metric "number of customers unsupplied" was selected.

A multi-layered modelling approach was adopted to represent the different complexities of the system under consideration. In context of modelling approaches, an example grid was used. The simple low voltage grid was assessed and abstracted to two quantities, P(production) and C(Consumption). A graph was used to respresent the grid, where each node is a simple LV grid with a P and C value, with multiple nodes each representing a LV grid. The network of LV grid was connected to a medium voltage grid monitored through an ICT substation. Using the abstraction, a fault tree is used to model the sequence of adverse events that lead to a change in system state.

Combining the metric and the above explained scenario, the system state was depicted in a resilience state space, where state was defined by P and C. Time t was not considered at this point to focus on the metric and avoid complexity. The concept of thresholds were discussed which determine consequences once the system state passed a certain threshold relative to the metric.
In context of a model, the discussed approaches were put together to define a stochastic reward net(SRN), through which a system state can be determined using reward functions obtained from SPNs used to determine P and C matching in the lower level.

These activities were accompanied by a seminar talk of the STSM Grantee on *Resilience in ICT enabled-power grids* on April 26, 2019.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The main results and approaches are described above. In addition, future collaborative work has been discussed.
The main results of the STSM include:

1. Initial steps towards a joint ICT and power system model
    a. Characteristics of power and ICT systems; Description of a combined system state.
    b. Introduction to Stochastic Activity Nets. SANs provide a opportunity to model system behavior in a well defined method based on conditions which is not available in Stochastic Petri Nets or Reward Nets.
    c. Approach to design a multi-layered model for ICT enabled-power grids that represents functional and structural aspects of a system during transient phases.

2. First steps towards a future publication with the host
    a. Model to quantify resilience(under continuous refinement)
    b. Resilience/ survivability analysis to minimize impact of ICT-related disasters
    c. KPIs to quantify effects of failures and its consequences
    d. Planned methods to obtain resilience metrics
    e. Expansion of model to large scale systems and larger use cases

FUTURE COLLABORATIONS (if applicable)

During the STSM, grounds for continued collaboration with the STSM host were laid in area of *modelling of a resilient ICT-reliant power systems*. Further joint work in the context of RECODIS WG3 are planned leading to a possible publication.